LAP 68-180 (RC)

FABRICATION TECHNIQUES FOR SHROUDED TITANIUM IMPELLER

Third Quarterly Progress Report
For Period Ending 31 March 1968

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Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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CONTENTS

INTRODUCTION AND SUMMARY

During the third quarter, effort on fabrication techniques of a shrouded titanium impeller was directed toward successful bonding of a simulated impeller sample, and fabrication of the full scale impeller pre-bond assemblies.

Two additional plasticity test specimens were pressed bringing the total to three. These tests indicated that a temperature of about 1850 degrees F with a pressure of approximately 2500 psi appears to yield the best bonding conditions for 5 Al-2.5 Sn (ELI) titanium alloy.

The simulated impeller with H-11 tool steel cores was repressed in an attempt to complete fillet formation with unsuccessful results. Difficulty was also encountered in core removal due to self-passivation of the H-11 tool steel in the acid bath. After core removal and chem-milling, this sample appeared about the same as the first simulated impeller that was bonded. On both of these samples, complete formation of the fillets did not occur in locations where the vanes intersected the shrouds with an acute angle. The final simulated impeller sample was bonded with titanium wire placed in the fillet voids during lay up. Inspection, after core removal and chem-milling, indicates fillets have been completely formed. Tensile specimens were taken from the final simulated impeller inlet areas and tested. Results yielded an ultimate tensile stress of approximately 122 K 51 with an elongation of 10-15 percent. These specimens broke approximately 1/4 inch below the fillet area. Photo-micrographs of the bond area show no indication of the bond joint.

Fabrication of the two full scale impeller pre-bond assemblies has been initiated and estimated delivery of the first unit is 30 June 1968. Design of the ceramic restrainer has been completed and procurement initiated. The cummulative expenditure to date is approximately 2776 hours and $82,734.

PLASTICITY TESTS

Two additional test specimens to determine optimum bonding conditions were pressed, bringing the total to three. Figure 1 shows the three plasticity test specimens that were pressed and the conditions under which they were processed. From these tests, it was concluded that using the highest temperature possible (about 1850 degrees F) without exceeding the beta transition temperature (1925 degrees F), and employing moderate pressures (about 2500 psi on the pressure plate) appear to give the most satisfactory results when bonding titanium alloy 5 Al-2.5 Sn (ELI). As shown in Fig. 1(a) considerable die deformation occurred using 4340 die material; however, this should not be a particular problem where the titanium completely surrounds the core material prior to application of heat and pressure.

DIFFUSION BONDING OF SIMULATED IMPELLERS

Simulated Impeller No. 3 (H-11 Steel Cores)

The simulated impeller with the H-11 tool steel cores was repressed in an attempt to complete fillet formation. The required axial compression was not achieved during the first cycle because the impeller assembly was not completely seated in the tooling when the initial zero reading was obtained. To prevent this during repressing, the assembly was placed under an initial pressure of 5000 psi cold and heated at a pressure of 2000 psi to assure seating of all parts. The sample was then pressed at 1750 deg F for 16 hours at pressures between 2000 and 3000 psi. This sample was recycled using the same split ceramic restrainer as on the first cycle; however, the retainer directly surrounding the trial impeller assembly was fabricated from 4340 steel in lieu of stainless steel. Inspection of the part upon removal from the retort indicated that fillet formation appeared satisfactory. However, after partial core removal it was observed that complete fillets did not form in some areas where acute angles existed (refer to Fig. 2). Difficulty was encountered in removing the H-11 tool steel cores because of self-passivation in the acid bath; however, the

reaction was re-initiated by removal of the surface layer formed by passivation. The third simulated impeller is shown in Fig. 3 after complete removal of the H-11 tool steel cores, but prior to chem-milling. As can be observed, complete formation of the fillets did not occur. Subsequent to removal of .020-inch of material by chem-milling, this sample appeared very much the same as the first simulated impeller that was bonded.

Based on the first two simulated impellers bonded and the three plasticity test specimens that were pressed, it was concluded that complete fillet formation did not occur because of friction between the core material and the titanium. The extent of filling or fillet formation appears to be largely a function of the hardware geometry. A minimum of filleting occurred in areas where the vanes made acute angles with the shrouds; however, almost complete filleting occurred where the vanes formed obtuse angles with the shrouds. With reference to the plasticity test specimens (Fig. 1), it may also be observed that as the slot to be filled in the die becomes narrower, the depth of filling is decreased.

Simulated Impeller No. 2 (Final Unit Bonded)

In view of the above conclusions and observations, it was decided to place 5 Al-2.5 Sn titanium alloy wire in the fillet voids of the final simulated impeller during lay up, in an attempt to aid in complete fillet formation during the bonding cycle.

Figures 4 through 8 show the final simulated impeller sample in various stages of assembly prior to bonding. This sample used a core material of 4340 steel; however, two of the cores were split in an attempt to simulate the effect of possible core shifting or deformation on passage geometry, whereas the first two samples bonded employed four one-piece cores. The configuration of the split cores is shown in Figs. 5 and 6. As shown in Fig. 7, titanium filler wires were placed only in fillet voids where the vanes formed acute angles with the shrouds.

The final simulated impeller sample was run through the bonding cycle under the following conditions:

Temperature	=	1850 Deg F
Pressing Time at Temperature	=	16 Hours
Pressure, psi (on end plate)	=	2500 (cold to seat parts) 2000 (during heating) 2000-2500 (at temperature)

The ceramic restrainer employed for the previous sample was also used for the final sample. Figures 9 and 10 show the final sample inlet and discharge area after bonding and tooling removal, but prior to core removal. As can be observed, complete filleting occurred at both the inlet and discharge areas of the simulated impeller sample. Examination of Fig. 10 shows that shifting occurred on one of the split cores. Figures 11 through 13 show the final simulated impeller sample after core removal, but prior to chem-milling. Examination of these figures shows that complete fillet formation has occurred. Figure 13 shows lines in the fillet area where a wire was employed to fill the void during lay up. These lines disappeared after chem-milling .010 of an inch material from all surfaces and thus do not represent cracks of any significant depth. Figures 14 and 15 show the final simulated impeller after chem-milling .020 of an inch of material from all surfaces. In Fig. 16, 0.040 of an inch of material has been removed from all surfaces.

Photo-micrographs and tensile specimens were taken from the final simulated impeller because it was representative of the conditions under which the full scale impellers will be bonded. Figs. 17(a) and 17(b) show photo micrographs of the bond area at magnifications of 50X and 250X, respectively. As may be observed, no indication of the bond joint is visible, although considerable grain growth has occurred. Figure 18(a) shows a photo micrograph of the non-bonded area at a magnification of 250X. In comparing Figs. 17(b) and 18(a), no significant differences are noted between bonded and non-bond areas. The photo-micrographs shown were taken of specimens from the impeller inlet.

Figure 18(b) shows three tensile specimens taken from the impeller inlet. These specimens were stressed in tension to failure with the following results:

Spec. No.	Ultimate Load - lbs	Ultimate Strength - KSI	Elongation 1/2 in. - %
2	762	122.5	15
3	843	124.3	15
4	567	122.1	10

The values of ultimate strength and elongation are typical for titanium alloy 5 Al-2.5 Sn at room temperature. As can be seen from Fig. 18(b), failure occurred well below the fillet area.

Comparison of Simulated Impellers

Figure 19 shows similar views of the three simulated impeller samples for comparison. The first and third samples bonded have .040 of an inch material removed by chem-milling from all surfaces, while the second sample bonded is shown with 0.020 of an inch of material removed. It can be observed from Fig. 19 that the fillets in the final sample are considerably larger than in the first sample. The radius of the fillet is increased during the chem-milling process.

FULL SCALE IMPELLER FABRICATION

Based on the successful results of the final simulated impeller sample, detail drawings of the full size impeller pre-bond assembly have been released for fabrication. Since no particular advantage of H-11 tool steel was noted during bonding of the simulated impeller samples, 4340 steel will be used as a core material. Design of the ceramic restrainer tooling for the full size impeller assembly has also been completed, and procurement has been initiated. Detail drawings for the ceramic restrainer are shown in Fig. 20.

PLANS FOR NEXT QUARTER

During the next quarter fabrication of the full scale impeller pre-bond assemblies and bond tooling will continue. Estimated delivery for the first pre-bond assembly is 30 June 1968.

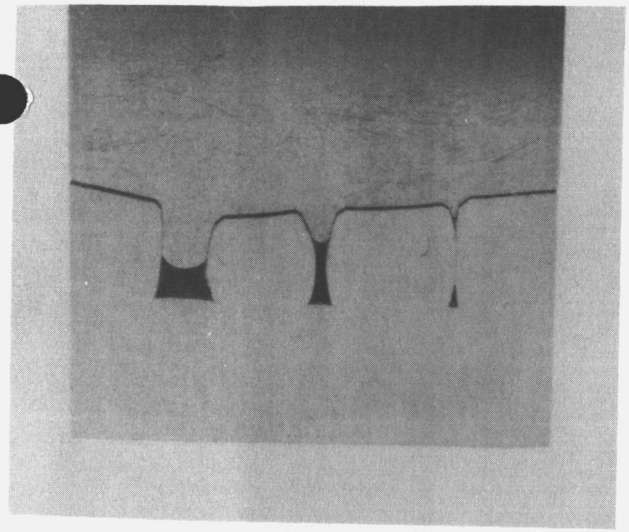

Fig. 1a

Titanium	5 Al-2.5 Sn (ELI)
Die Material	4340
Pressing Temp, °F	1750
Pressing Time, hrs.	16
Pressure, psi	2000-4000 (4000 - 3 hrs)

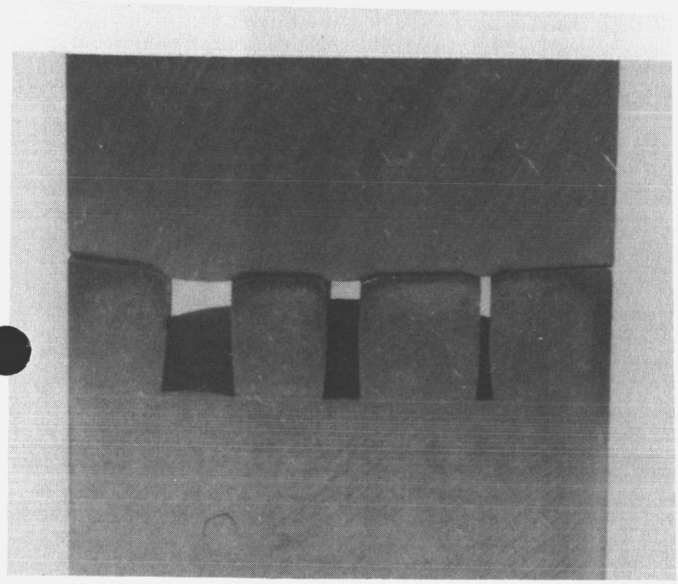

Fig. 1b

Titanium	5 Al-2.5 Sn (ELI)
Die Material	4340
Pressing Temp, °F	1650
Pressing Time, hrs.	16
Pressing Time, psi	2000

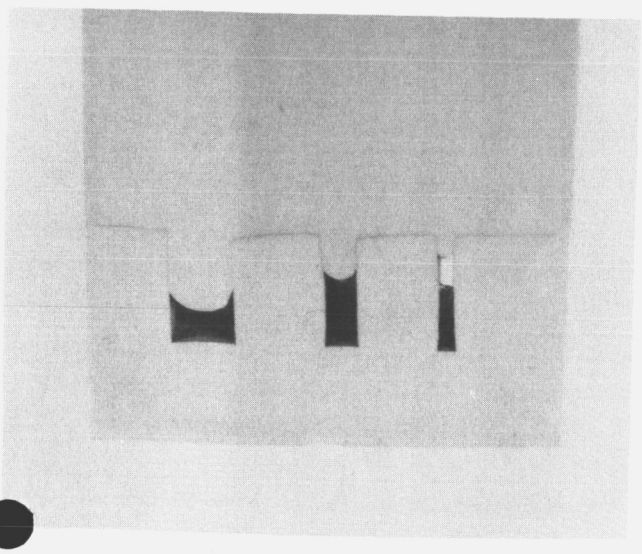

Fig. 1c

Titanium	5 Al-2.5 Sn (ELI)
Die Material	H-11
Pressing Temp, °F	1850
Pressing Time, hrs.	16
Pressure, psi	4500 - cold 2000 - heating 2000-3000 at temp.

Figure 1. Plasticity Test Specimens

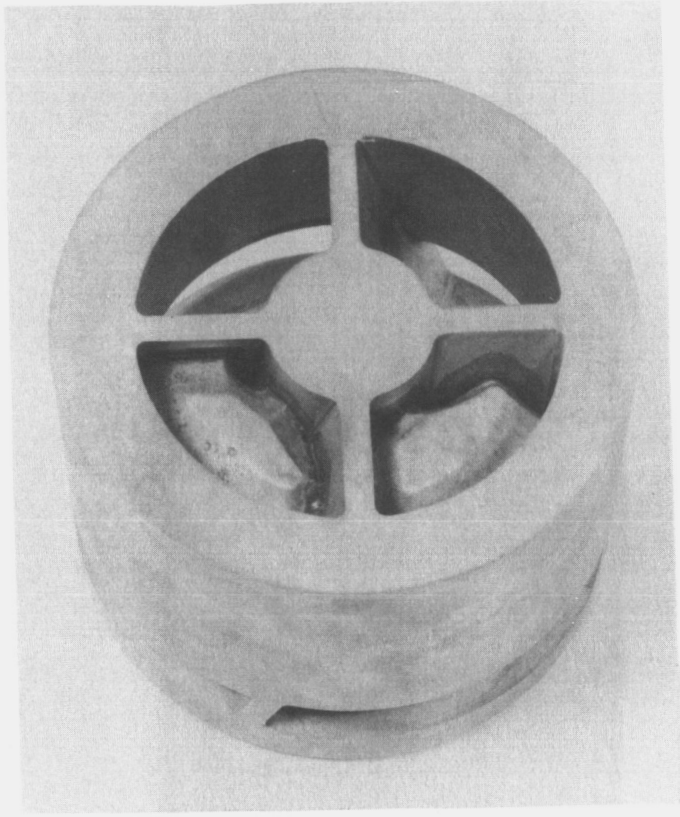

Fig. 2 (a) Eye View of Sample Impeller Showing Partial Removal of H-11 Tool Steel Cores

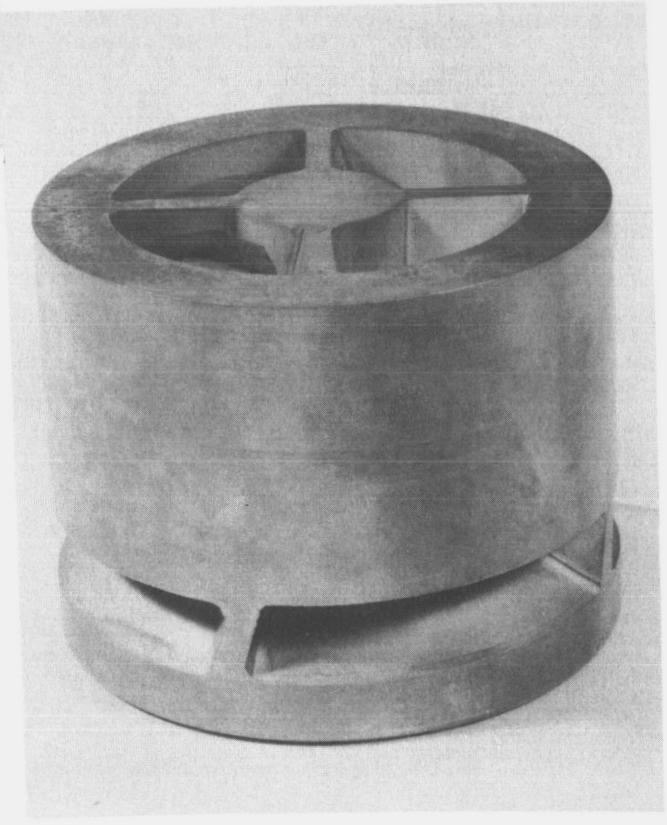

Fig. 2 (b) Discharge View of Sample Impeller Showing Partial Removal of H-11 Tool Steel Cores

Figure 2. Repressed Third Trial Impeller Sample After Partial Core Removal

Figure 3. Third Simulated Impeller After Removal of H-11 Tool Steel Cores

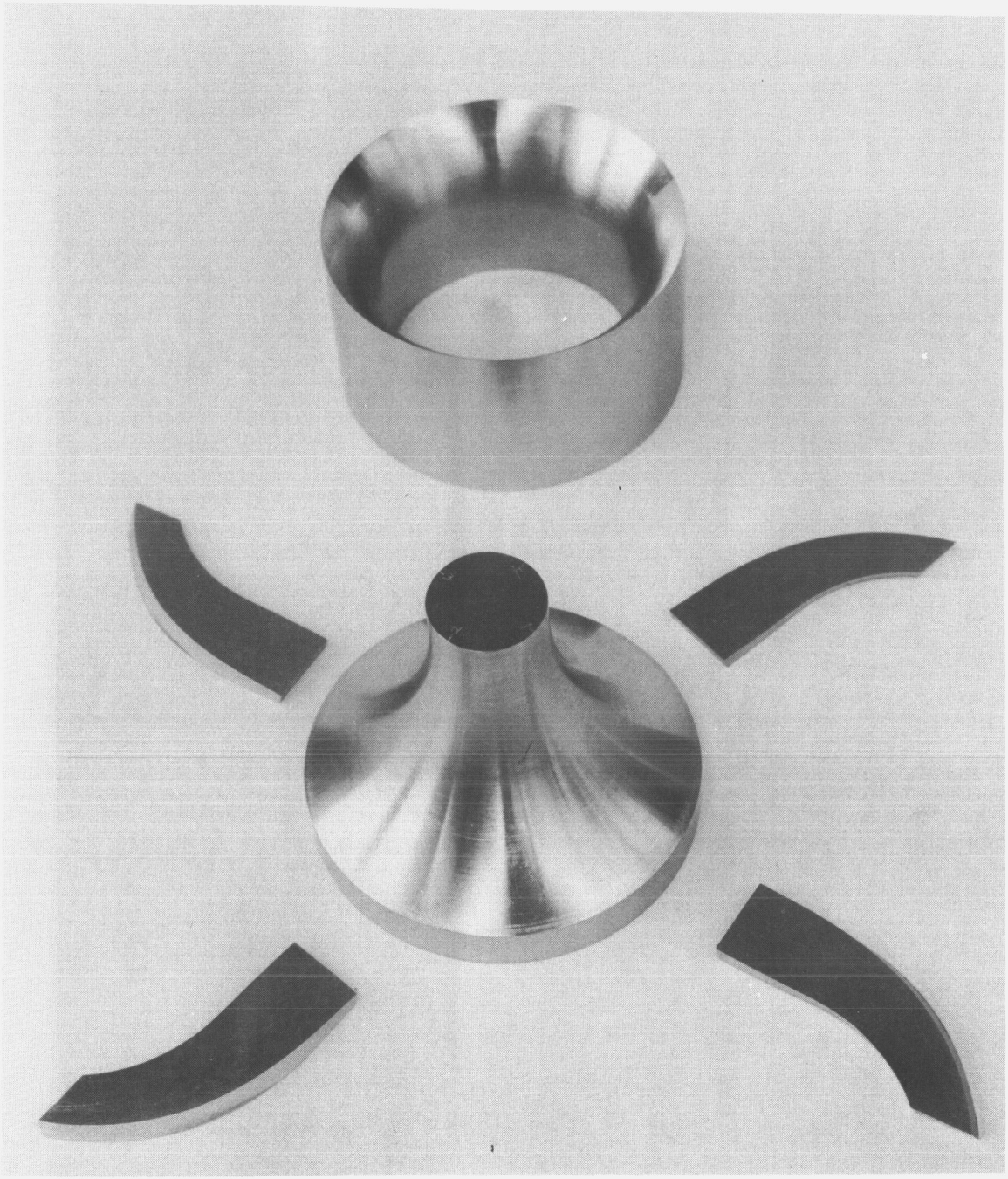

Figure 4. Final Simulated Impeller Sample Showing Vanes and Shrouds

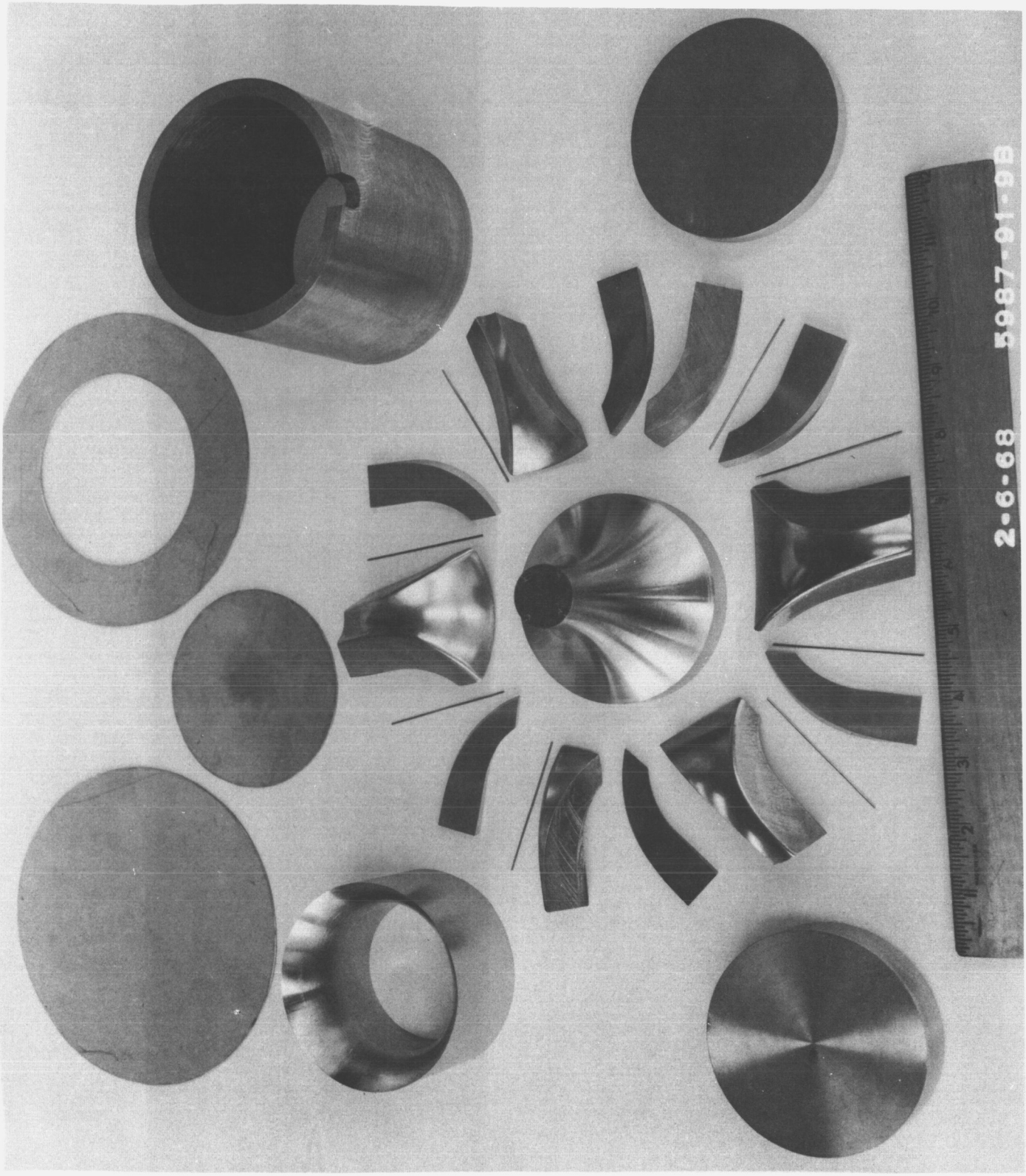

Figure 5. Final Simulated Impeller Sample Showing Complete Bond Assembly Before Lay Up

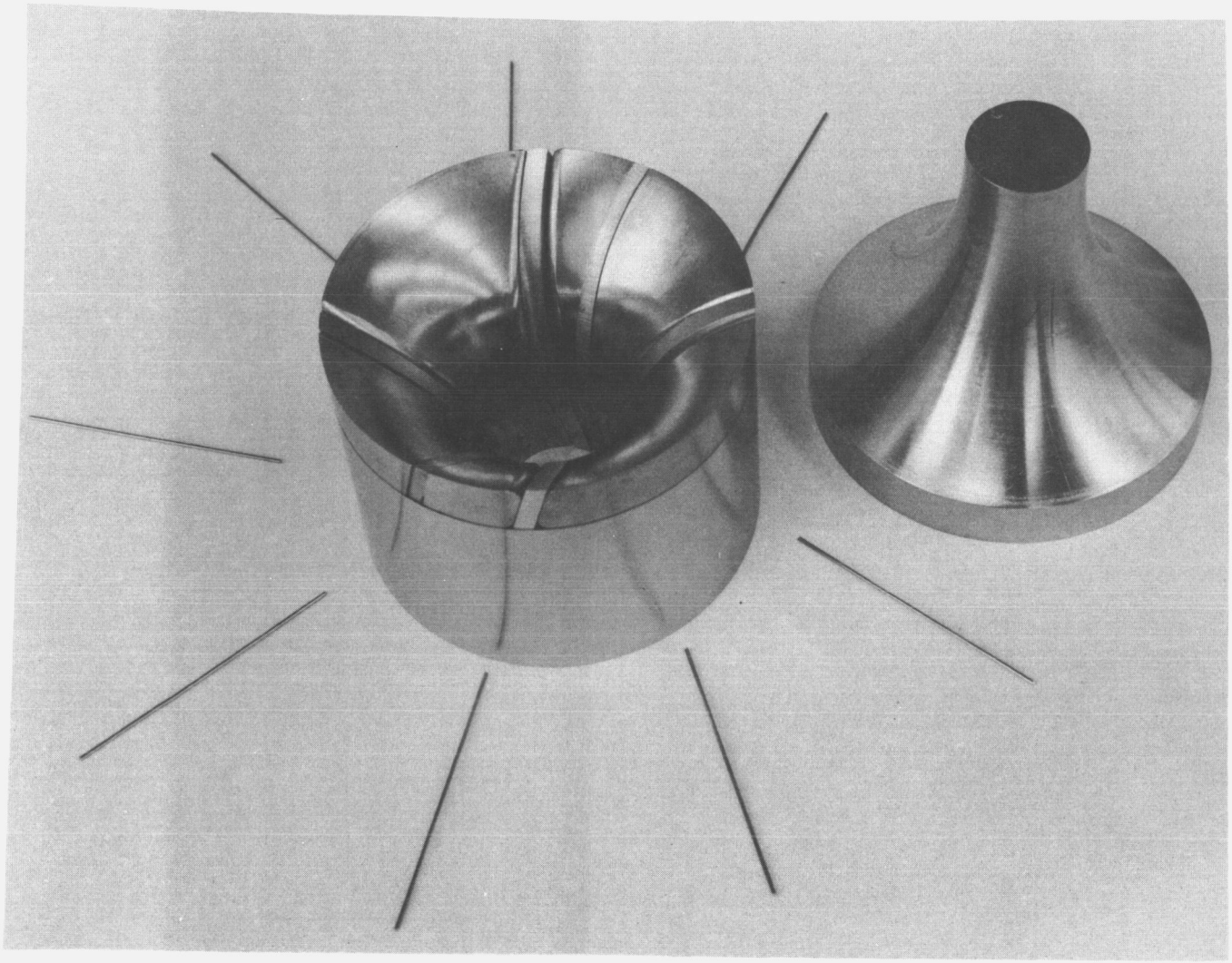

Figure 6. Final Simulated Impeller Sample Showing Partial Lay Up of Pre-Bond Assembly

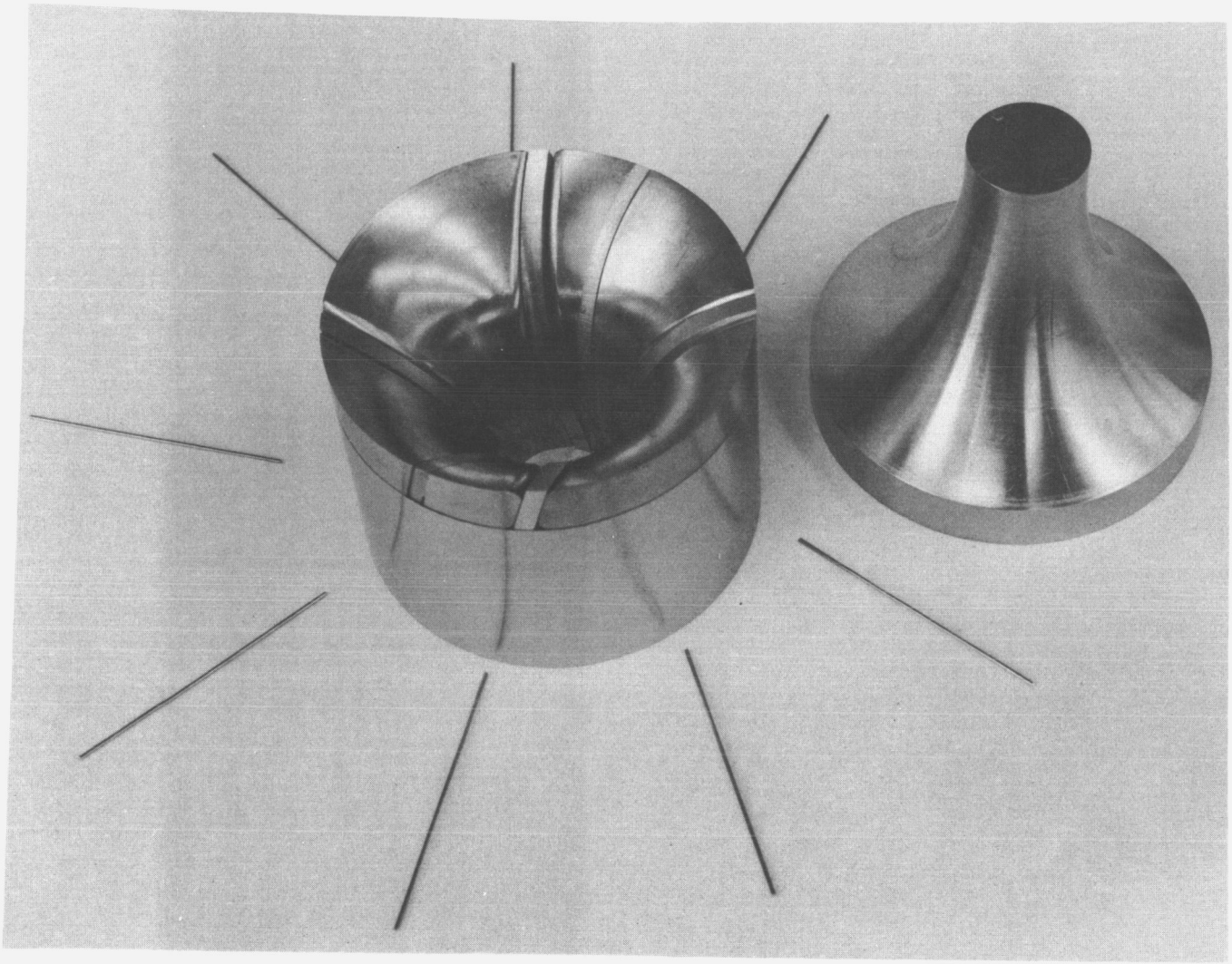

Figure 6. Final Simulated Impeller Sample Showing Partial Lay Up of Pre-Bond Assembly

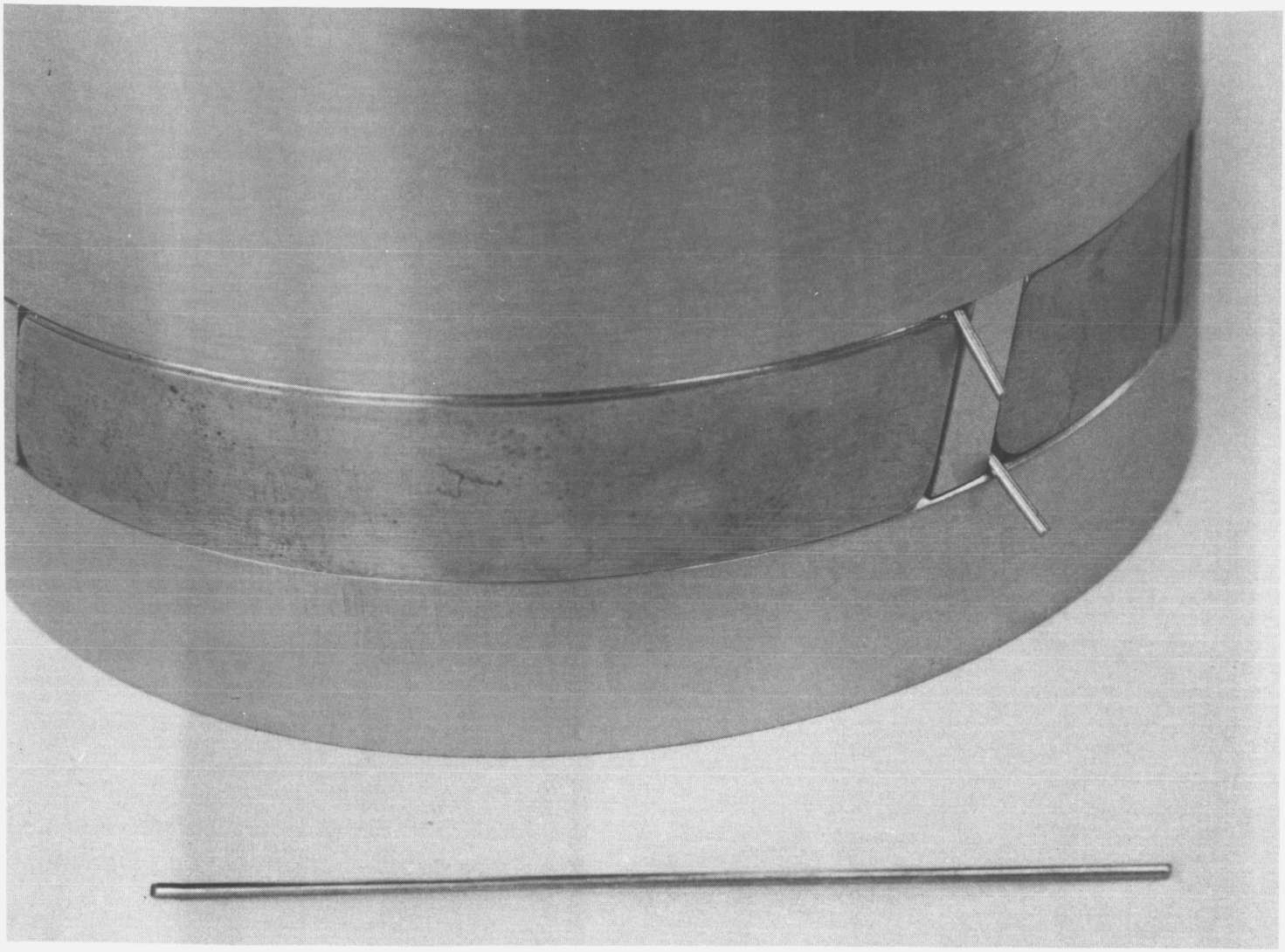

Figure 7. Final Simulated Impeller Sample Showing Titanium Wire Inserted in Fillet Voids Where Vanes Form Acute Angles with Shrouds

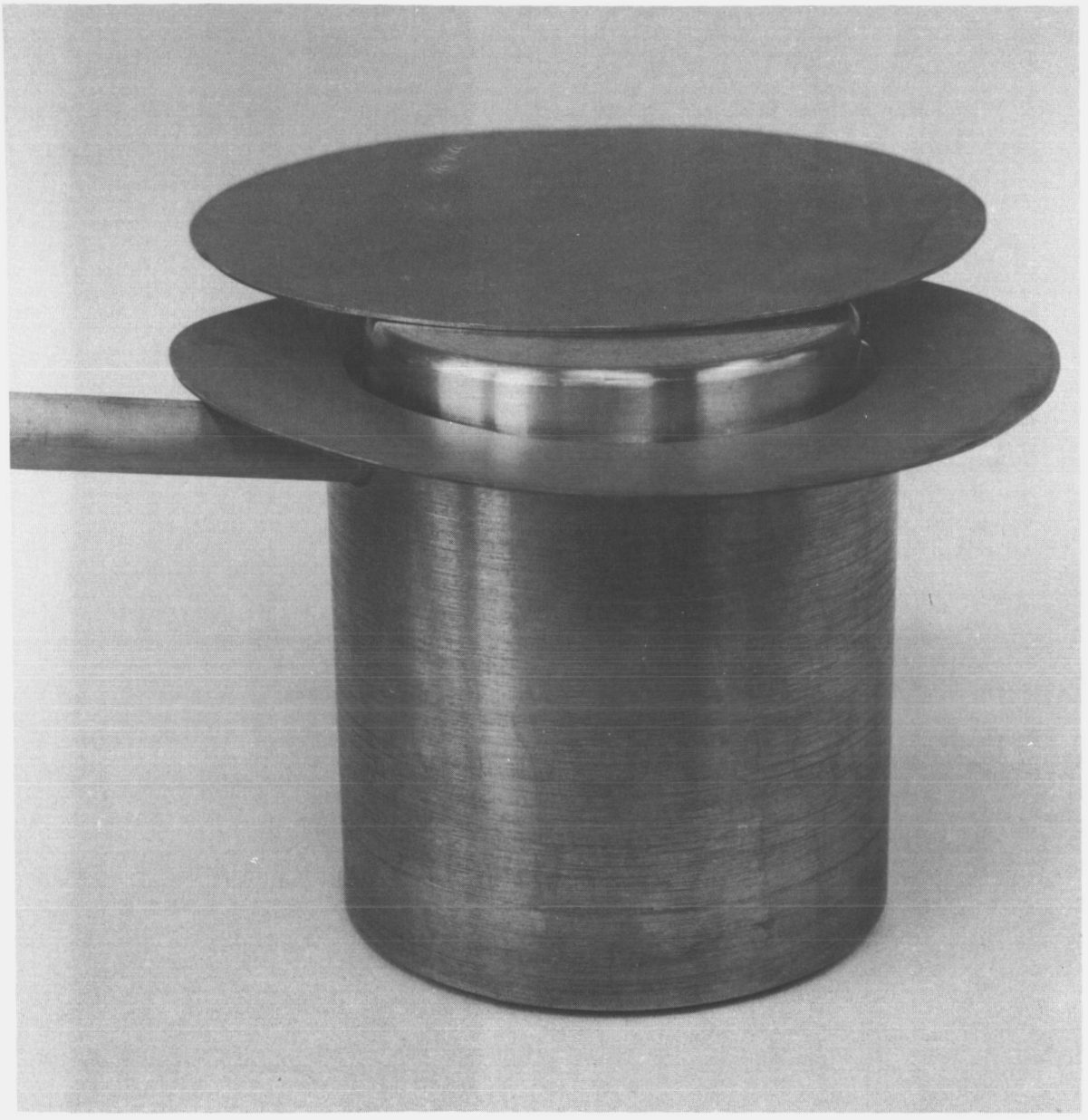

Figure 8. Final Simulated Impeller Sample Showing Pre-Bond Assembly After Lay Up Prior to Welding of Retort

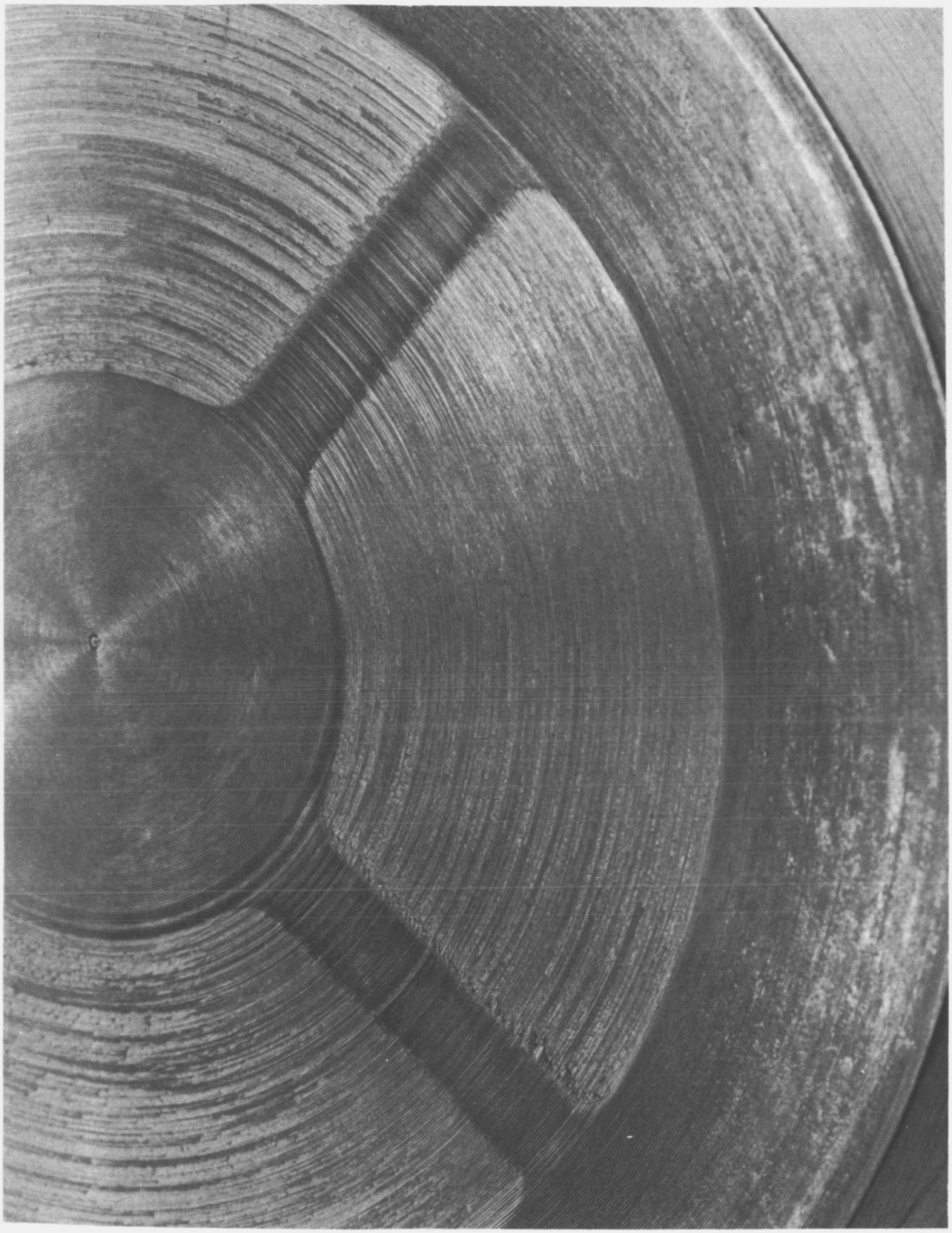

Figure 9. Final Simulated Impeller Sample Showing Inlet Area After Bonding and Tooling Removal

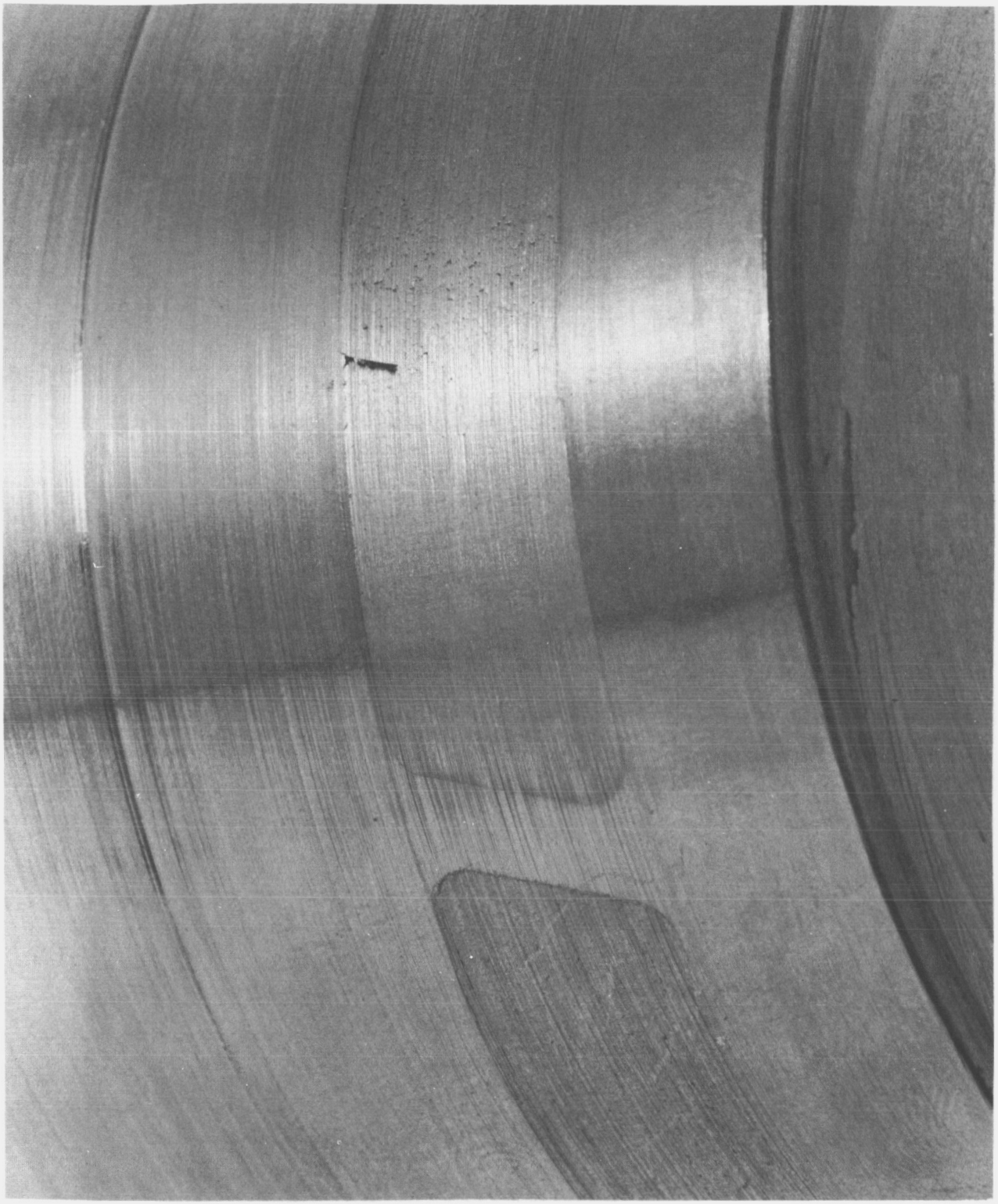

Figure 10. Final Simulated Impeller Sample Showing Discharge Area After Bonding and Tooling Removal

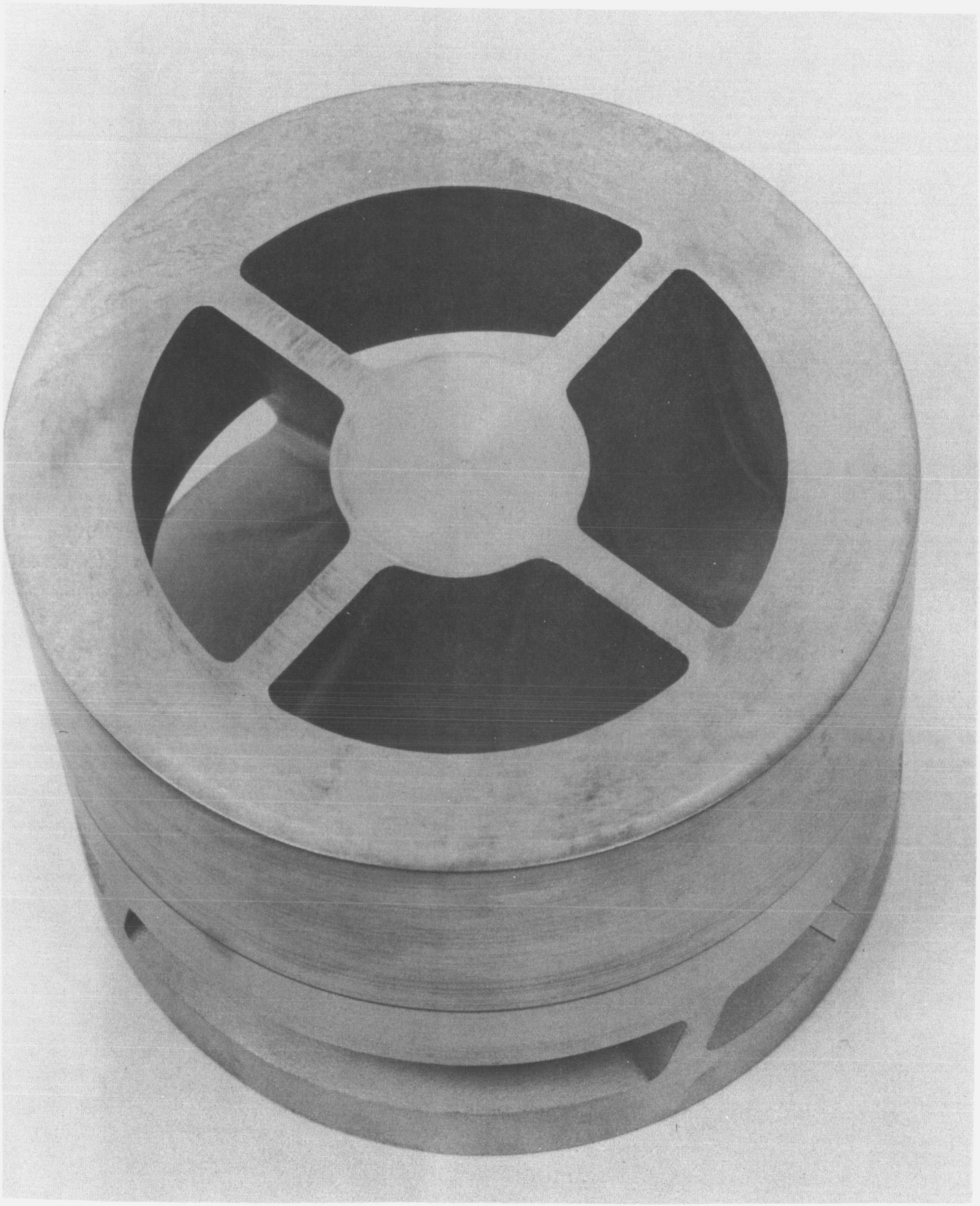

Figure 11. Final Simulated Impeller Sample Showing Inlet Area After Removal of 4340 Steel Cores

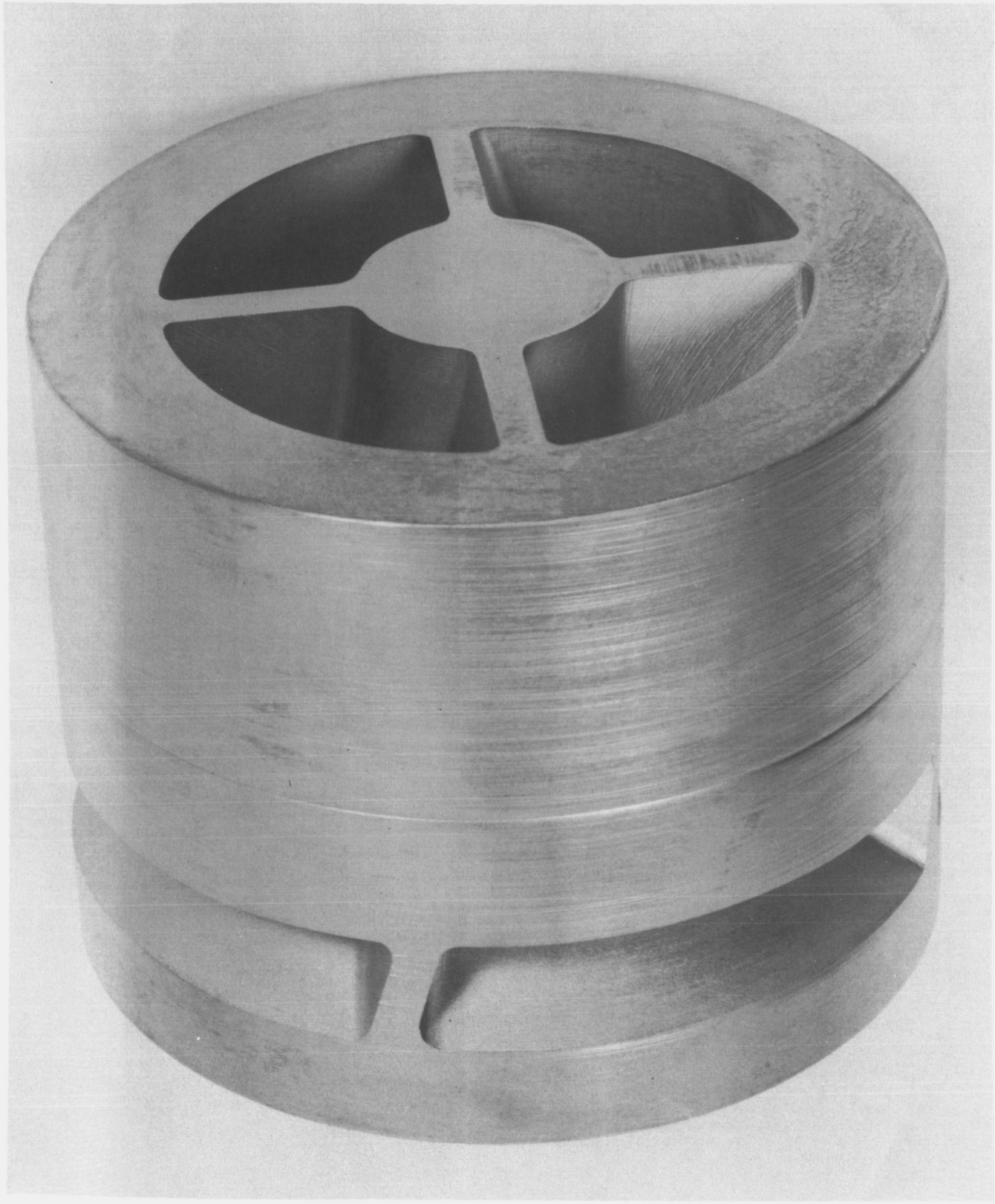

Figure 12. Final Simulated Impeller Sample Showing Inlet and Discharge Area After Core Removal

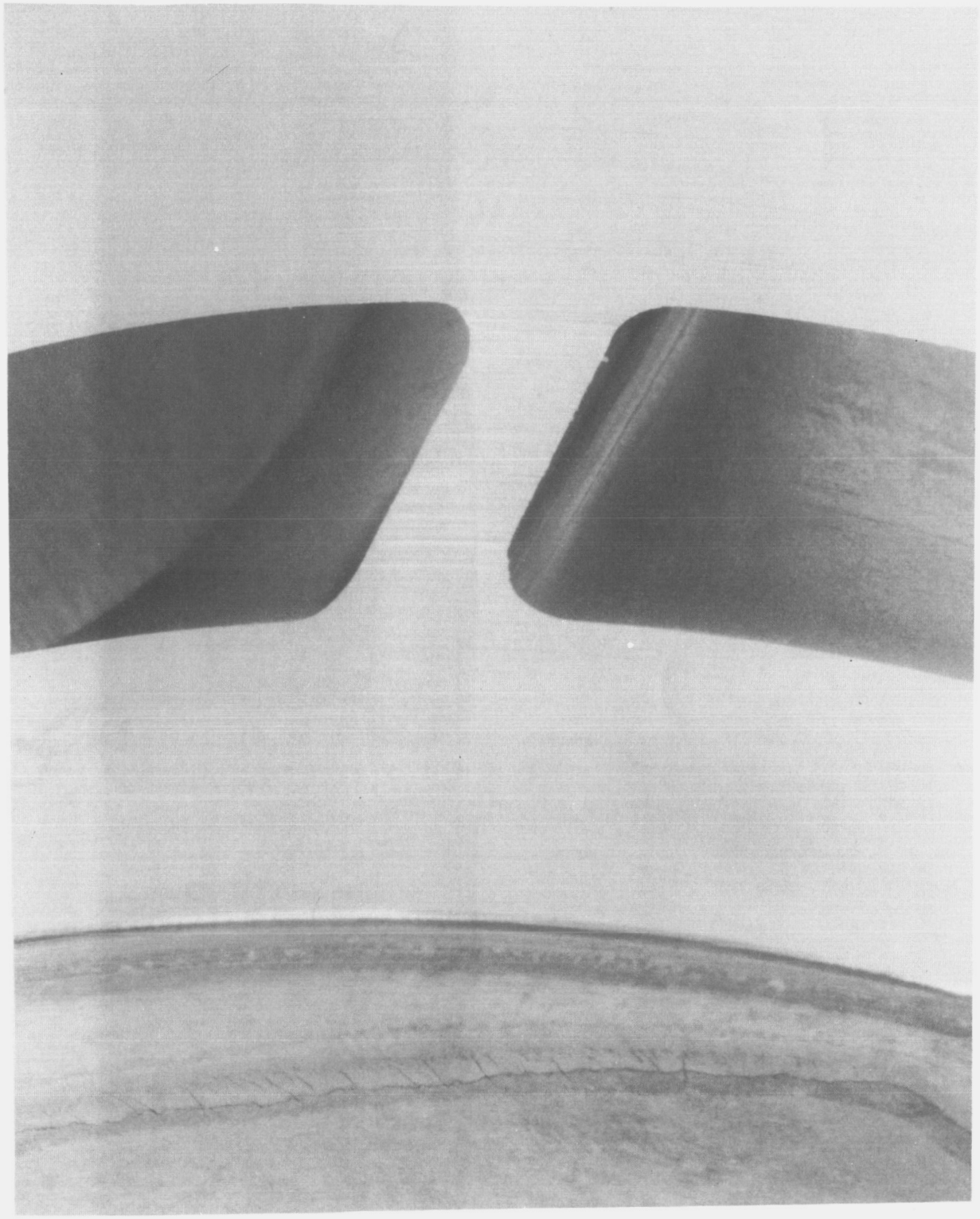

Figure 13. Final Simulated Impeller Sample Showing Close Up of Discharge Area After Core Removal

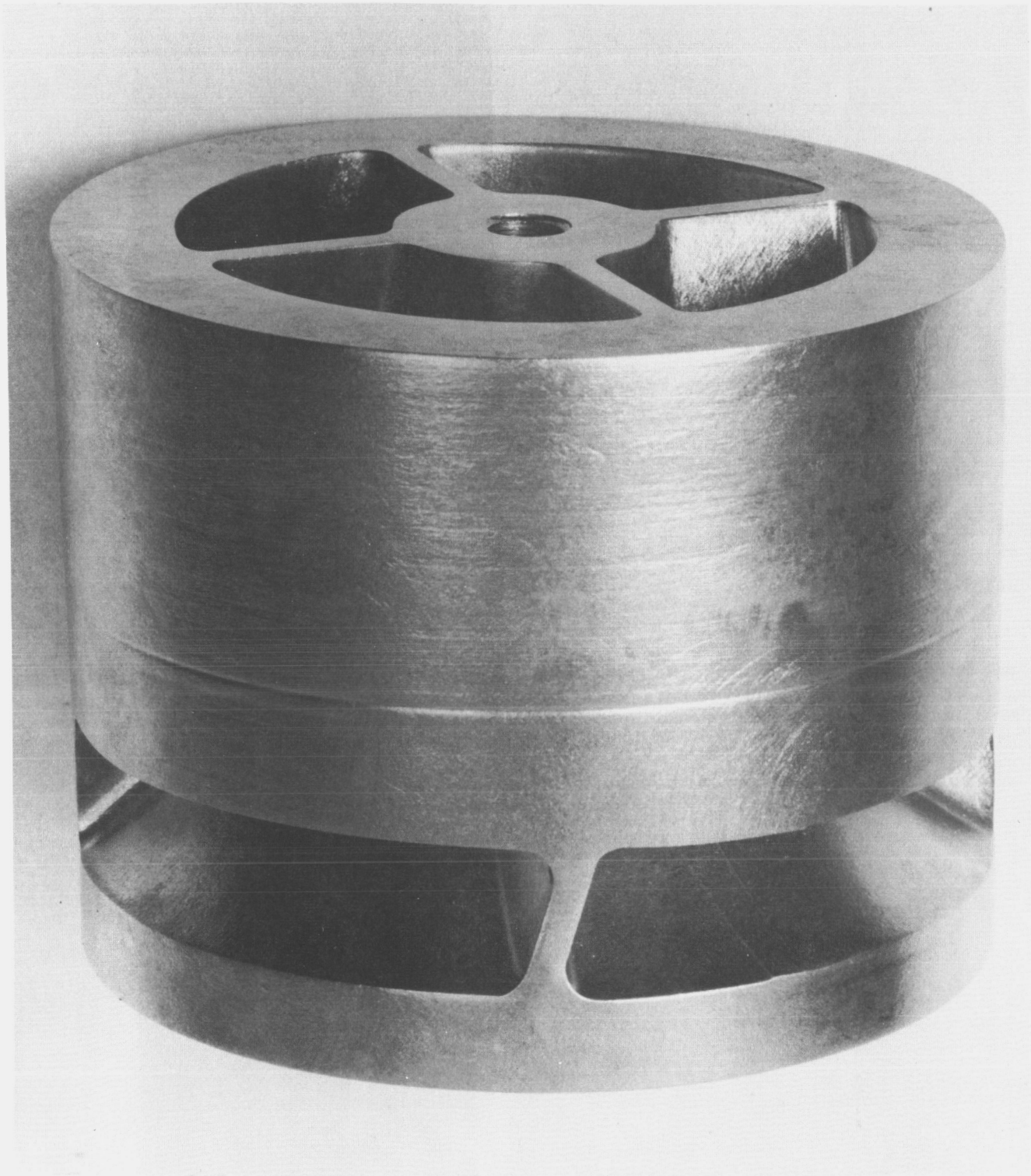

Figure 14. Final Simulated Impeller Showing Discharge Area After Removing 0.020 of an Inch of Material From All Surfaces by Chem-Milling.

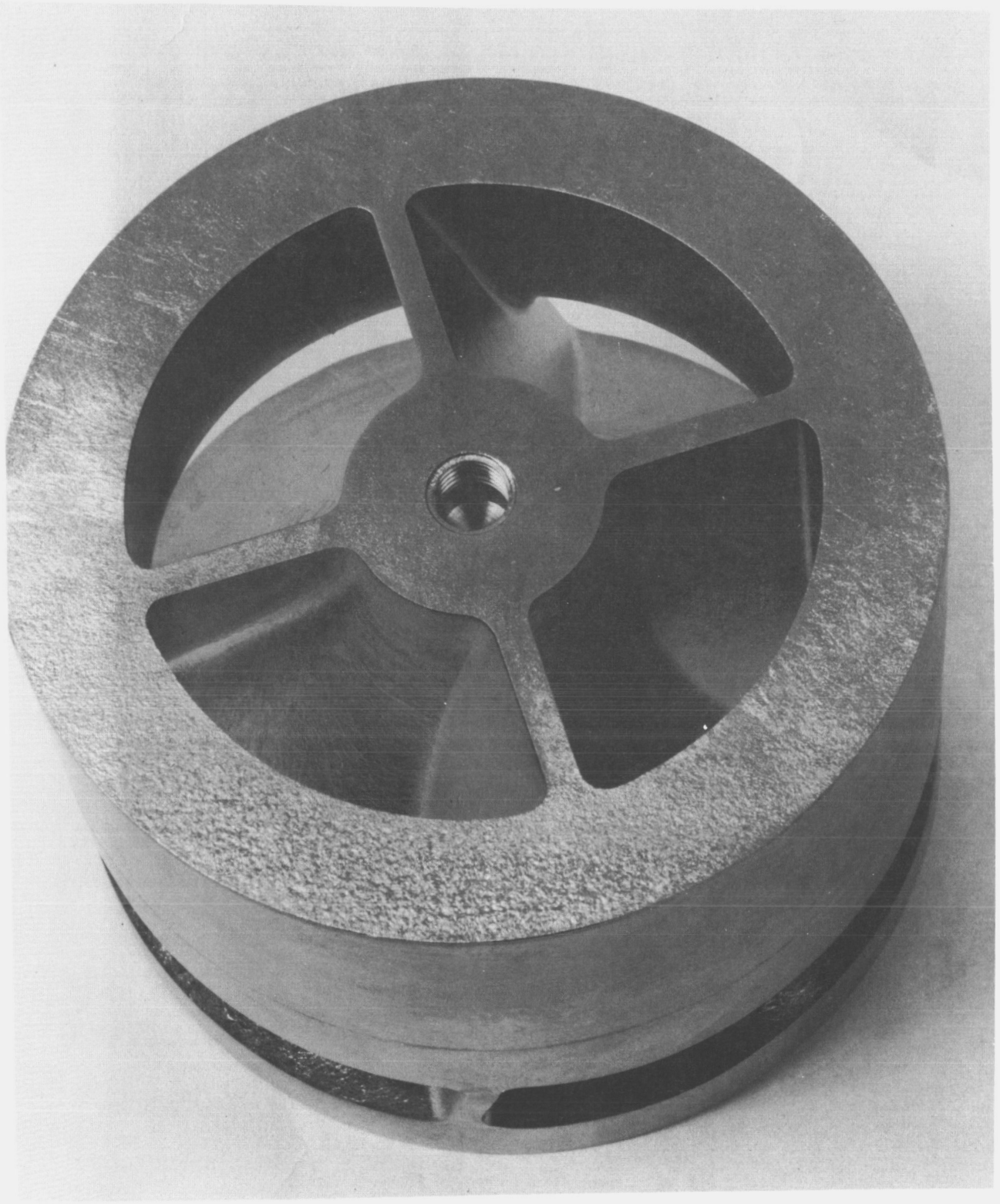

Figure 15. Final Simulated Impeller Showing Inlet Area After Chem-Milling 0.020 of an Inch Material From All Surfaces.

Figure 16. Final Simulated Impeller Showing Inlet Areas After Chem-Milling 0.040 of an Inch Material From All Surfaces.

Figure 17a. Photo-Micrograph of Bonded Area. 50X

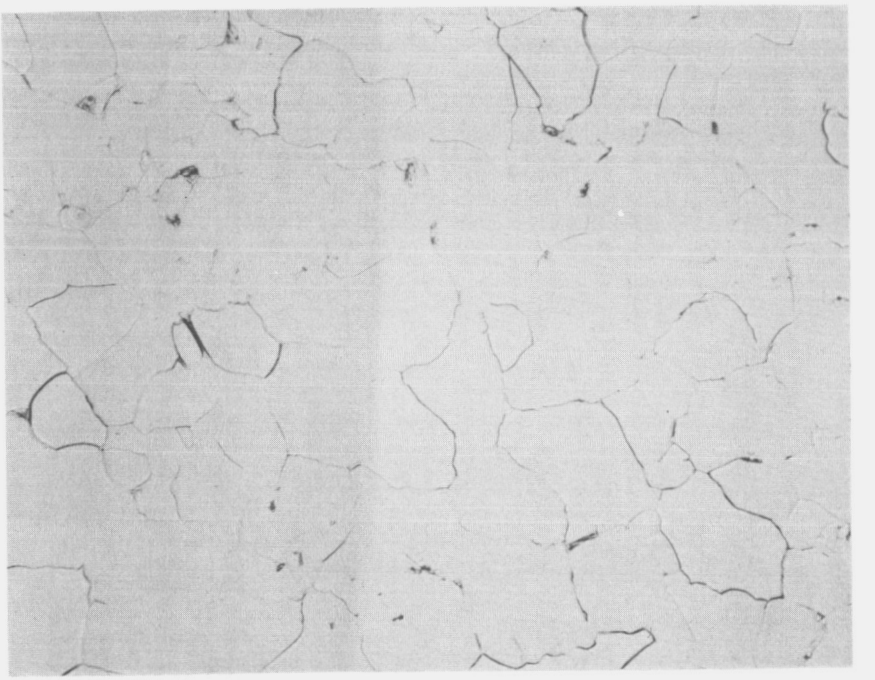

Figure 17b. Photo-Micrograph of Bonded Area. 250X

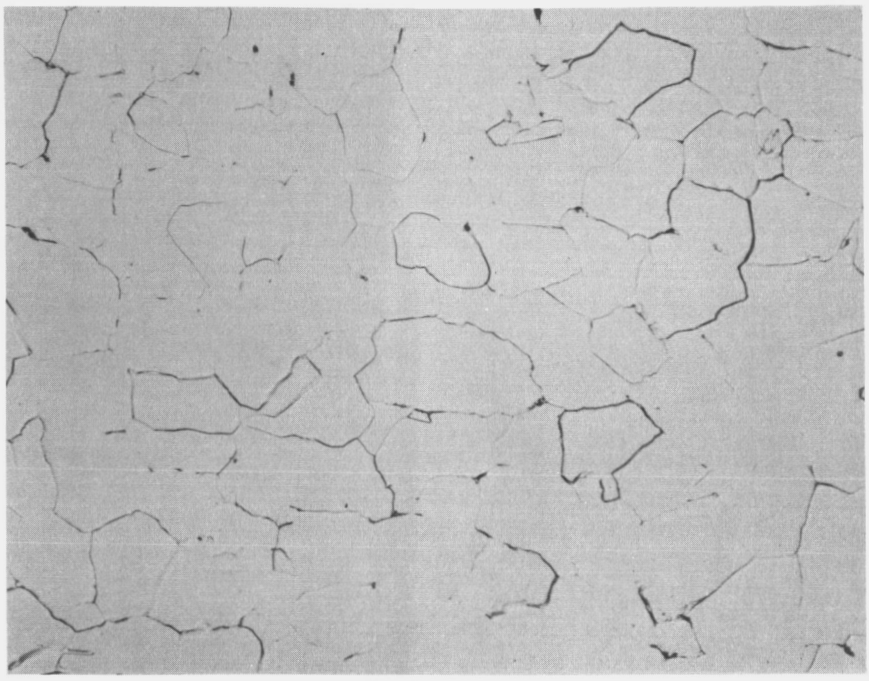

Figure 18a. Photo-Micrograph of Non-Bond Area. 250X

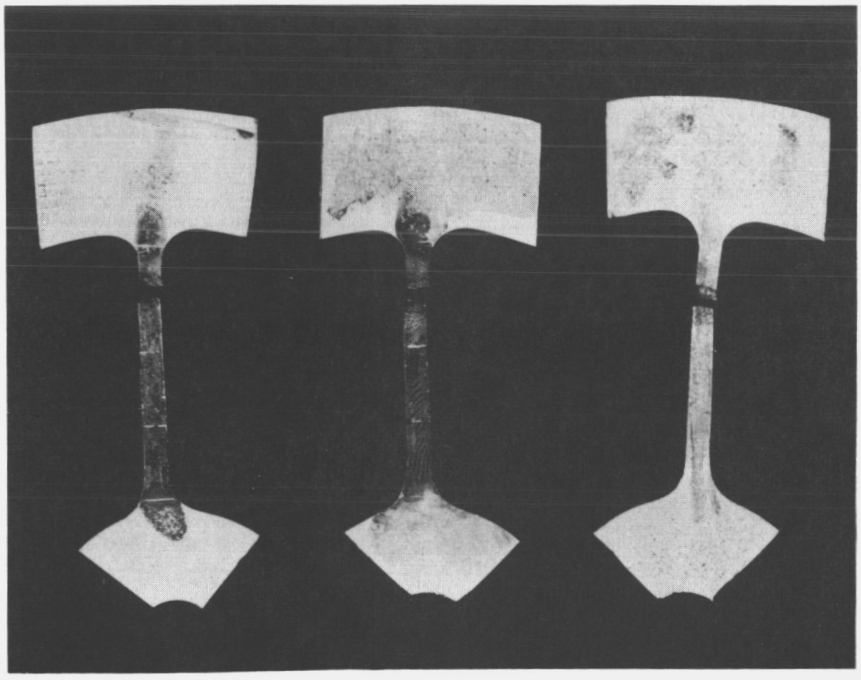

Figure 18b. Tensile Specimens Taken From Simulated Impeller Inlet Area

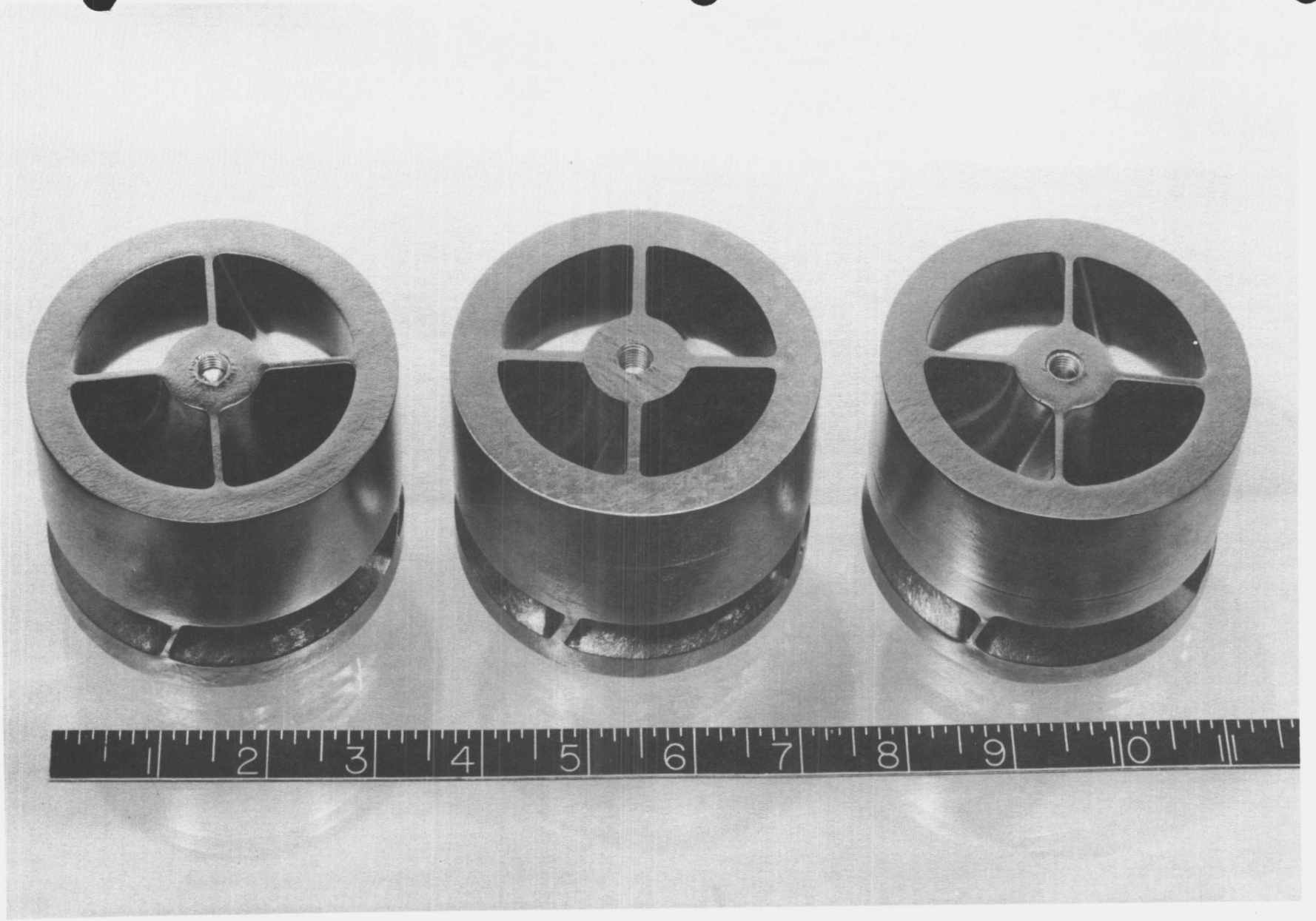

Figure 19. Simulated Impeller Samples Bonded. Sample at Left was First Unit Bonded, Center Sample the Second, and Unit at Right the Final. It Should be Noted that the First and Final Sample Bonded Have .040 of an Inch Material Removed From All Surfaces While the Middle Unit has 0.020 of an Inch Removed From All Surfaces.

12 11 10

IF -003 IS FLAME CUT, THIS AREA MUST BE SPOTFACED TO PROVIDE A FLAT TRUE SURFACE FOR SEATING OF -005

11.00 (REF)

22.00 (REF)

.4250

(-003) B REQD
(NUT)
DRILL 1.9323 +.0035 -.0000
TAP 2-16 UN-3B
P.D 1.9594 +.0032 -.0000
PER SPEC MIL-S-7742
CADMIUM PLATE -005 PER LA0109-015

(-005) CHAM 45° x 3/4
THD 2-16 UN F-3A
BEFORE PLATING P.D 1.9584 +.0000 -.0030
AFTER PLATING P.D 1.9594 +.0000 -.0040
PER SPEC MIL-S-7742
4.50 MIN FULL THDS BOTH ENDS.

12 11 10

FOLDOUT FRAME #1

FOLDOUT FRAME #2

44.25 (REF)

100% PENETRATION

36.50 DIA

SYM ABOUT ℄

(#3) B REQD OPTIONAL - MAY BE FLAME CUT PER NAA CORPORATE PROCESS SPEC LA0103-006 OR EQUIV.

.133 DIA 126 HOLES IN EA HALF
252 HOLES REQD TOTAL (2 HALVES)
252 #10 SUPPRGREY HIGH RESISTANCE WIRE ELEMENTS 255" IN LENGTH, EXTENDING 6 INCHES PAST TOP & BOTTOM
SLIP FIT.

9.00

18.00

1.75

.25 FOR GLASROCK CEMENT

21.50

(#2) 2 REQD

SYM ABOUT ℄

(#2) 2 REQD
OPTIONAL - MAKE -002 INTO 6 SEGMENTS, THUS -002 12 REQ'D.

300 TON CLIFTON HYD PRESS (REF)

15.06 (MIN R(X)) + .187 + .50 (REF)

31 45° SR

.43

.37

.37

10.75

¼ CLEARANCE EACH SIDE FROM 300 TON PRESS (REF)

24.40

2.25

.000

.030

(#4) 4 REQD
CADMIUM PLATE -004 PER LA0109-015

2

RETORT (REF)

-006 (REF)

-003 (REF)

3.30 TYP

6.65

3.30

3.30

13.30 (REF)

FRAME

FRAME

FOLDOUT FRAME

FOLDOUT FRAME #3

1

ZONE	LTR	DESCRIPTION	DATE	APPROVED
A		1. MAY BE REWORKED 2. CANNOT BE REWORKED 3. RECORD CHANGE 4. NEW SHOP PRACTICE 5. PARTS MADE OK		
		1. -006 PLATE RECD & -003 RECD FITTING WAS -003 FITTING REVISE L/M TO AGREE 2. ADD WELD REQMNTS FOR -003 TO -006 3. REMOVE INTERMITTENT WELD 4. L/M -003 MAT - NRS PLATE 1020-1030 WAS 1025		
7		5. -002 2 RECD WAS [illegible] & .133 DIA 126 HOLES WAS 63 HOLES	4-2-68	J Sullivan

FOLDOUT FRAME II 5

		QTY		PART NO	DESCRIPTION	CODE	MAT	SPEC	ZONE
①		2		-006	PLATE		NRS PLATE 1020-1030	.1250 x 3.30 x 39.00	7
		8		-005	NUT		4340 [illegible]	3 x 3 [illegible] 2.25 L	10
		4		-004	ROD		4340 [illegible]	2.0 x 24.60	8
①		8		-003	FITTING		NRS PLATE 1020-1030	[illegible] x 7.00 x 11.50	7
		2		-002	MAS ROCK		—	COMMERCIAL ①	7
				-001					

Figure 20. Ceramic Restrainer

FOLDOUT FRAME II 4

3

① GLASROCK PRODUCTS, INC
341 E. REDONDO BEACH BLVD, GARDENA, CALIF.

NOTES: UNLESS OTHERWISE NOTED:

FASTENER CODING

CONVENTIONAL AND BLIND RIVETS SHALL BE INSTALLED PER NAA SPECIFICATION

HEAT TREAT [illegible] 180 KSI [illegible] (-003)

[illegible] NOTED FOR -005 IN ZONE 8 & 10

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE PRINT

APPROVED BY

NORTH AMERICAN AVIATION, INC. / LOS ANGELES DIVISION

CERAMIC HEATING PLATTENS [illegible] CLAMP FOR ROCKETDYNE IMPELLER FOR 300 TON PRESS

SIZE	CODE IDENT NO	
J	43999	PDB 0003

SCALE 1/2 SHEET